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EXPERIENCE IN THE UNITED STATES

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For thirteen years, from 1934 to 1947, high quality sweetpotato starch was manufactured and marketed in the United States. One factory of moderate capacity began operation in 1934 and continued through the 1944-45 season. A second much larger factory was in production during the 1945-46 and 1946-47 seasons. In both instances the feasibility of the manufacturing process and the marketability of the products were adequately demonstrated. In neither case, however, was the problem solved of obtaining sweetpotatoes for raw material in sufficient volume and at a cost low enough to prevent financial loss in the over-all operations. Hence no sweetpotato starch has been produced commercially since early 1947.

The earlier of the two sweetpotato starch factories, which was set up in 1934, was an experimental plant operated by a farm cooperative at Laurel, Mississippi. In this plant the manufacturing process, and the quality and uniformity of the products were progressively improved. Sufficient sweetpotato starch was produced to establish it as a market commodity, to demonstrate its suitability and advantages for a variety of commercial uses, and to open up a demand for many times the output of the factory. On the basis of the experience at Laurel, the United States Sugar Corporation erected a large new factory at Clewiston, Florida, which operated during the 1945-46 and 1946-47 seasons. The plant at Laurel was discontinued after the 1944 season,

when the prospective initiation of operation by the new plant in Florida made it appear that the experimental plant had served its purpose in pointing the way to establishment of commercial sweetpotato starch manufacture. Unfortunately, the new factory also had to close after the 1946-47 season because of unforeseen agricultural problems in obtaining a sufficient volume of sweetpotatoes without prohibitive cost.

Laurel Starch Enterprise: Beginning in 1934, processes developed in the laboratories and pilot plant of the USDA Bureau of Chemistry and Soils for production of high quality starch from sweetpotatoes were carried to commercial scale in the Laurel Starch Plant of Sweet Potato Growers, Inc., at Laurel, Mississippi. This enterprise was sponsored initially as a rural rehabilitation project by the Emergency Relief Administration and was carried on to 1945 essentially on an experimental basis, with financial assistance and supervision by the Farm Security Administration, assistance and advice in raw material production by the Mississippi Agricultural Experiment Station, and technical assistance and supervision in manufacture of starch by, successively, the Bureau of Chemistry and Soils, the Bureau of Agricultural Chemistry and Engineering, and, eventually, the Bureau of Agricultural and Industrial Chemistry through its Southern Regional Research Laboratory at New Orleans.

With the aid of the USDA agencies, a plant with an initial capacity of about 10 tons of starch per 24-hour day was installed in a former lumber mill. A history of the enterprise, description of the process and equipment, and discussion of related

considerations up to 1938 are given in the following published article:

"Manufacture of Sweet Potato Starch in the United States"
H. S. Paine, F. H. Thurber, R. T. Balch, and W. R. Richee
Industrial and Engineering Chemistry, Vol. 30, pp. 1331-1348 (1938)

In general, the basic process and equipment were as described in that article. Subsequently, however, numerous minor changes and several major improvements were effected. Beginning in 1940, settling of the starch in a series of large tanks was substituted for tabling as the initial stage of concentration and purification of the crude starch. In 1941, equipment for large-scale blending of the finished starch in carlot quantities was designed by the Southern Regional Research Laboratory and placed in operation, with resultant economy of labor and operating costs, and reduction of dust hazards. Improved procedures were developed and applied for chemical control of the starch extraction, purification, and finishing operations, and for production of modified starch. The initial output capacity of some 10 tons of finished starch per 24-hour day was eventually nearly doubled.

In the process finally adopted, the washed whole sweetpotatoes were ground in a hammermill with process water (lime water-starch milk) from the countercurrent screening system. The ground pulp was passed over the first set of shaker screens where the liberated starch was washed out through 3XX silk (about 55 mesh). The pulp was then flushed up with countercurrent starch milk, reground in a second hammermill, and the remaining liberated starch was washed out in a four-stage countercurrent shaker screening system in which the overflow pulp from each stage was successively

flushed up and agitated with countercurrent starch milk and then rescreened through 5XX silk (about 65 mesh). The pulp from the last stage of screening was flushed up with fresh saturated lime water (most of the lime water used in processing was introduced here), drained to about 95% moisture on a rotary screen or reel, further dewatered to about 73% moisture by passing through two roller presses in succession, and was then dried for cattle feed in a rotary steam tube drier.

Throughout the grinding, screening, and starch-purification operations, the process waters were maintained at an alkaline reaction of about pH 9.0 by the lime water. By such use of lime water a sufficiently alkaline reaction is maintained to keep pigments in solution, until the starch is separated from the process water; and at the same time the calcium ion flocculates certain sweetpotato constituents (pectin substances) keeping them with the pulp when the starch is washed out, and facilitating drainage of the pulp in screening and pressing.

The crude starch milk from the first set of shaker screens contains all the starch washed out in the countercurrent screening system after the second grinding of the pulp, as well as the starch washed out after the primary grinding. It was passed through a set of fine shaker screens (7XX silk, or about 75 mesh), to remove small quantities of pulp which passed the first screens with the starch, and was then settled for 12 to 18 hours in a series of large tanks. The overlying liquor, "fruit water", containing the soluble constituents of the sweetpotatoes, (principally sugars and protein), and some fine pulp which settles

more slowly than starch, was drawn off. The settled crude starch was flushed up with water containing sufficient lime to impart a pH of about 9.0, brought to a density of about 5° Beaumé, passed through a set of fine shaker screens (160-mesh bronze) to remove further fine fiber, and tabled on concrete starch tables.

The settled starch on the tables was flushed off with fresh water to an average density of about 12.5° Bé and fed to the bleach tanks. (The starch carried over in the tabling overflow tailings was concentrated by a combination of tank settling and solid basket centrifuging, and retabled.) The starch suspension was then bleached to a high degree of whiteness with alkaline hypochlorite, after which the excess hypochlorite was eliminated by sulfur dioxide, and the pH adjusted to the desired level. When unmodified starch was in production, the starch suspension from the bleach tanks was dewatered directly to 35-40% moisture content in perforate basket centrifugals. The wet starch was carried to a mixing hopper above the drier through a warm air conveyor which removed several percent more of moisture. The starch was then dried to an average of about 12% moisture in a batch-type vacuum drier. The dry starch was pulverized in a hammermill and bolted through silk in a rotary reel. Thence it was conveyed to the blending system where it was mixed uniformly to the required viscosity grade, with or without admixture of modified starch. The starch was then rebolted and bagged for shipment.

Thin-boiling starch, for applications requiring low viscosity, and for blending with mill-run starch, was produced by controlled acid modification of the suspension from the bleach tanks and readjustment of the pH before dewatering and drying as in the case of mill-run starch.

Clewiston

<u>Florida Starch Enterprise:</u> In December 1945, the large new factory of the United States Sugar Corporation commenced operation at Clewiston, Florida. In this very modern plant, with the cooperation of the Southern Regional Research Laboratory, the basic starch manufacturing process developed at Laurel was translated to large-volume operations employing the latest-developed equipment for continuous mechanized processing. The plant had a nominal capacity of 120 tons of finished starch per day. The essentials of this later development are described in the publication:-

> "Starch Production in the Florida Everglades"
> B. A. Bourne and F. H. Thurber
> <u>Southern Power and Industry</u>, Vol. <u>64</u>, No. 6, pp. 44-47, 98 (1946)

The basic process and flow-sheet of this new factory were essentially those developed in the Laurel plant; but quite a number of changes in the processing units were introduced. High-speed attrition mills were used in lieu of hammermills for both primary and secondary grinders. Continuous solid-bowl centrifugals or classifiers of the horizontal type were used for separation of protein, sugars, and other solubles from the ground sweetpotato pulp before screening. High-frequency vibrating screens were used in place of reciprocating shaker screens. High-speed continuous centrifugals took the place of settling tanks and

tables for thickening and purification of the starch slurries. Rotary vacuum filters were provided for washing the purified and bleached starch prior to dewatering. Continuous, horizontally-mounted centrifugals and indirect-heat rotary driers took the place of batch-type suspended perforate basket centrifugals and a vacuum drier for dewatering and drying the starch, respectively.

Two seasons' experience in this new factory demonstrated that, while a number of changes or adjustments in the equipment would be desirable, the basic process and flow-sheet were sound and that the overall starch manufacturing process was technologically feasible. Curtailed production was due to the limited supply of sweetpotatoes available. If the agricultural side of the enterprise had been advanced as far as the manufacturing side, a substantial sweetpotato starch industry might have been established. Unfortunately, problems not forecast by the earlier experimental results were encountered when the field production of sweetpotatoes was scaled up to the large acreage necessary to sustain the factory at full capacity.

CONSIDERATIONS AFFECTING THE ECONOMIC FEASIBILITY OF SWEETPOTATO STARCH MANUFACTURE

Volume of Operations: Experience in the projects summarized above indicated that manufacture from sweetpotatoes of starch of high quality and uniformity can be carried out economically only on a fairly large volume basis. The characteristics of sweetpotatoes and the necessity of operating during much of the season at relatively warm temperatures require processes and equipment which are difficult to adjust to small-volume, low-cost units. The factory at Laurel, Mississippi was originally

designed to turn out some 10 tons of starch per 24-hour day. As the plant was operated from year to year, however, it became apparent that sustained higher volume would be necessary to make efficient use of the labor and equipment and carry the overhead costs. The capacity was eventually increased to 15 tons or somewhat more per day; but even when operated at this volume, maximum efficiency was not realized. Hence the trend was toward larger, rather than smaller plants. The new factory in Clewiston ~~Florida~~ had a capacity about 8 times that of the Laurel plant, or some 120 tons of starch a day. Admittedly, a factory of such large size, with its heavy requirement of raw material to sustain efficient operation at full capacity, does not fit the needs of small sweetpotato-producing communities. At the best, however, the evidence indicated that an efficient plant should have a capacity of at least 20 tons of starch per 24-hour day.

<u>Raw Material Requirements:</u> Given the best of processing plants and necessary auxiliary facilities of adequate water supply, waste disposal, and transport, a sweetpotato starch enterprise can hardly succeed unless the following basic requirements are met:

1. An existing or potential <u>assured</u> supply of suitable sweetpotatoes sufficient to keep the factory operating at full capacity.
2. Sustained deliveries of raw material over a sufficiently long period of the year to avoid excessive off-season overhead.
3. Delivery of the sweetpotatoes to the factory at a cost permitting profitable operation at the prices obtainable for the finished products.

The smallest capacity plant considered practicable from the experience here being considered, namely, one turning out about 20 tons of starch per 24-hour day, will require approximately 120 tons (about 4,300 bushels of 55 pounds each) of sweetpotatoes per day. These potatoes should reach the factory as soon as possible after digging and should be delivered at about the same rate as processed. Sweetpotatoes are very perishable, especially when rough handled as they have to be for industrial use, and deterioriate rapidly, particularly in warm weather, if allowed to pile up for any length of time before grinding. Regularly sustained delivery is also essential for economical plant operation. It costs money when the factory has to shut down because of temporary lack of raw material, or when raw material piled up ahead of plant capacity begins to rot.

The crop production setup should permit harvesting at profitable yield levels and sustained plant-capacity deliveries over a season of at least 100 days, preferably 120 days. Since storage of the type used for stock being held for the food market is far too costly for industrial stock, factory operation must be confined to the harvest period. At the best, this seasonal operation, as in processing sugarcane in Louisiana, necessitates carrying all annual fixed charges and overhead on the operating season. If this season is too curtailed, profit ceases. At 120 tons daily, the starch factory will require a total of some 12,000 to 16,000 tons or about 436,000 to 580,000 bushels of sweetpotatoes for 100 to 120 days' grinding. Production of this raw material should be concentrated within moderate hauling distance of the factory. Sweetpotatoes are too heavy and too perishable when

rough handled to permit economical trahsport for long distances before processing.

Raw material requirements of the magnitude of the foregoing would be well nigh impossible to fill by use exclusively or predominantly of culls or local surpluses from market sweetpotato enterprise. A reasonable proportion of culls can be worked in; but the greater part of the raw material should consist of high-starch white sweetpotatoes grown specifically for the purpose. As a sole source of raw material, culls are too variable and uncertain in quantity and processing quality to sustain a starch factory in continuous capacity operation. Furthermore, the lower content of starch and the higher contents of pigments andmother non-starch constituents in tablestock sweetpotatoes increase the manufacturing costs per pound of starch and lower the yield.

During the period when interest and activity in sweetpotato starch production were high, much research effort was expended by the U. S. Department of Agriculture and several state experiment stations, notably Louisiana and Mississippi, to develop, by breeding and/or selection, improved varieties of sweetpotatoes for starch manufacture and other industrial uses. Two which proved outstanding in yield of crop, starch content and processing quality were the Louisiana Experiment Station variety, L-5, and the USDA-Beltsville variety, B-196. These varieties were released for commercial production under the names "Pelican Processor" and "Whitestar", respectively. The former replaced the older Triumph variety for the last two seasons of the Laurel operations and was the sole raw material for the Clewiston ~~Florida~~ factory. With its

very low content of pigments and its high content of starch, it processed exceptionally well, with good recovery of very clean starch. "Whitestar" did not become available in sufficient quantity for factory trials; but in experimental pilot-plant tests it likewise demonstrated very superior processing quality.

The ultimate factor, however, which limits the economic feasibility of sweetpotato starch manufacture in the United States was, and still is, the high cost of growing the raw material. Given the best of varieties, favorable cultural and seasonal conditions, and maximum practicable mechanization of the cultural and harvesting operations, the labor (man-hours per acre) required to produce the crop remains excessive.

This problem was not overlooked when the Laurel undertaking was initiated in 1934. It was recognized that, even with the comparatively low costs of common farm labor then prevailing, cash value as little as ten cents per hour, sweetpotatoes could hardly be produced by the methods then existing with a cost low enough to allow profit to the grower at the prices payable by the starch factory. The hope was that reduction of the labor requirement through mechanization and other improved practices, development of more prolific varieties of sweetpotatoes of higher starch content, and consistent attainment of the high acre-yields of which the crop is capable under suitable conditions would eventually make profitable the production of sweetpotatoes for industrial utilization. In the meantime, with the cooperation of the

Surplus Marketing Administration, crop diversion payments were made available in most of the seasons to supplement factory payments and give growers sufficient aggregate return to encourage their continued support in supply of raw material.

Even thus, a crop of sufficient volume to sustain full-season capacity operation of the factory was never attained during the 11 years of the project's existence. Substantial progress was made in development of better high-starch sweetpotatoes, as noted above. Adequate mechanization proved a greater problem than had been anticipated; but significant advances were made in equipment for transplanting and harvesting. After 1941, however, when the United States entered World War II, the impacts of the emergency on the availability and cost of labor and other items rapidly outstripped the savings effected by improved production methods. Eventually the Laurel factory ceased operation after the end of the 1944 season, when diversion payment support had been withdrawn, and when increased costs of raw material and competition with wartime demands for sweetpotatoes for dehydration made it impossible to continue starch manufacture without excessive losses.

In the case of the ~~Florida~~ Clewiston enterprise, the results of experimental plantings had encouraged the prospect that the very high yields of sweetpotatoes obtainable and the long growing and harvesting season would offset high acre costs of production sufficiently to bring the raw material costs down to a level at which the factory could operate with satisfactory profit. However, when it came time to scale up production to a volume sufficient to

sustain the large plant, agricultural problems not forecast by the experimental work were encountered, and the average yields fell far short of the estimates. After two seasons of operation at limited capacity, starch manufacture was terminated in 1947.

Since that time, the situation has not altered in any way to encourage revival of interest in manufacture of sweetpotato starch in the United States. The costs of farm labor have continued to advance and the supply has dwindled. Despite some further developments in mechanization incident to growing sweetpotatoes for the food market, the acre costs remain high and have entailed problems, even with the relatively high prices obtainable for tablestock.

<u>Other Requirements for a Starch Factory:</u> Other basic requirements for a sweetpotato starch factory are adequate power, water, and waste disposal facilities. About 70 to 90 kw. hours of power and around 2,500 to 3,500 gallons of clear water per ton of sweetpotatoes processed were required in the operations described above. (The amounts of power and water vary with the particular type of starch purification system used.) The waste waters amounted to 2,000 to 3,000 gallons per ton of sweetpotatoes ground. These waste waters may carry as much as 1% of dissolved and suspended organic matter (chiefly sugars and protein) and offer a disposal problem. At Laurel the factory was permitted access to the waste outlet of a large industrial plant located nearby; but curbing of this outlet was threatened in the later years of operation. In the case of the Clewiston Florida enterprise, an extensive waste-treatment system constituted a major item in

the capital investment. As of the present time, appropriate waste-treatment facilities are a must for any starch factory. The time has passed when the effluents can be allowed to drain into existing natural water courses. As is mentioned below, recovery of certain byproducts from the waste waters could reduce the disposal problem; but it cannot be completely eliminated.

Outlet for Sweetpotato Starch: Sweetpotato starch, as manufactured and marketed by the plant at Laurel, Mississippi, demonstrated its suitability for use in most of the applications of starches. For a number of specialized applications where root or tuber starches were indispensable or preferred, it proved equal or even superior to tapioca or white potato starches. For some uses it possessed properties which appeared to give it a unique advantage over other starches.

In the industrial field, Laurel sweetpotato starch displayed some distinct advantages over other starches then available for textile warp sizing and finishing of dyed goods. Of the aggregate output of the Laurel factory (about 11 million pounds) over 7 million pounds went into textile uses. The starch found favor for laundry finishing; proved suitable for beater sizing of paper; and was satisfactory for certain adhesives. A leading manufacturer of dry cell batteries depended on one grade of sweetpotato starch exclusively to meet critical requirements in production of a special-duty cell. In the food field favorable reports were received from trials in baking; preparation of pudding-mixes, pie-fillings, and salad dressings; and man-

ufacture of gums and other types of confections.

As of the present, some 25 years later, it is difficult to appraise the probable position of sweetpotato starch in the competitive market, were the product now manufactured. In those former years, to a greater extent than now, the specific inherent characteristics of different varieties of starches, whether cereal, root, or tuber, determined their suitability for given uses, except non-critical applications where price was the governing factor. This situation may ~~still~~ exist in some instances. During recent years, however, the versatility of a given variety of starch has been greatly expanded by development of diverse modifications and derivatives. In addition numerous synthetic products have invaded the field of applications once the monopoly of starches.

IMPLICATIONS OF SOME RESEARCH FINDINGS YET TO BE EVALUATED UNDER COMMERCIAL MANUFACTURING CONDITIONS

Recovery and Utilization of Byproducts: In the former operations at Laurel, Mississippi and Clewiston, Florida, the sole byproduct of starch manufacture was the residual pulp, which was dewatered, dried, and used for cattlefeed. This disposition of the pulp eliminated a major waste-disposal problem and contributed significantly to the overall economy of the operations.

Extensive laboratory and pilot-plant investigations demonstrated that the waste effluent ("fruit water") from the first stage of concentration and purification of the crude starch in the Laurel process (settling tank overflow) constituted a good substrate for propagation of feed yeast (Torula utilis), with substantial reduction in the content of organic matter.

(In the Clewiston factory the corresponding waste water was the effluent from the continuous solid-bowl centrifugals through which the gound sweetpotatoes were passed before going to the screening system.)

In other investigations by the Southern Regional Research Laboratory, technologically feasible processes and equipment were developed for flocculation, concentration, and dewatering of the protein in the "fruit water" to recover a crude protein concentrate which could be added back to the dewatered byproduct pulp and dried to yield a feed of substantially higher nutrient value than the non-fortified pulp. (Where tablestock sweetpotatoes were included in the raw material ground for starch, most of their content of carotene was carried down and concentrated with the crude protein.)

Termination of all commercial manufacture of sweetpotato starch eliminated opportunity for factory-scale evaluation of the foregoing byproduct recovery processes, singly or integrated; and reliable data are lacking to appraise their economic feasibility in terms of savings on waste-treatment and disposal, or added byproduct credit in the overalll operations.

More details of the byproduct recovery processes and the products obtained are presented in:-

"Sweetpotatoes: More than Starch"
P. R. Dawson, L. H. Greathouse, W. O. Gordon
<u>Yearbook of Agriculture 1950-51</u> (U.S.Dept.Agr.)
pp. 195-203

SIMPLIFIED STREAMLINE STARCH PROCESS

P.R. Dawson, E.A. Gastrock

One of the final projects carried out before termination in 1950 of research on sweetpotato starch manufacture comprised development on a large pilot-plant scale of a simplified, highly mechanized continuous process which took advantage of the latest improved equipment then available. Such a process could be adapted to an efficient, compact starch factory of low labor requirement, but with a daily capacity of some 20 tons of finished starch, the minimum for maximum economy of operation. A flowsheet of the pilot-plant process appears in -

"Instrumentation for Pilot Plants", pH Control Aids in Production of Sweet Potato Starch"
R.M. Persell, E.F. Pollard, W.F. Guilbeau, L.H. Greathouse, Industrial and Engineering Chemistry Vol. 42, pp. 931-32 (1950)

The setup contemplated the needs of a revived sweetpotato starch industry if or when the economics of growing the raw material might improve.

Opportunity was never afforded for full-scale evaluation of the process. As of 1966 the findings are well out of date insofar as they apply to specific items of equipment. In the intervening 20 years some greatly improved equipment for manufacture of starch has become available, and has been adopted in many instances in the corn and potato starch industries. No information is yet available, however, to appraise the performance of the new equipment with sweetpotatoes.